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BIOMEDICAL APPLICATIONS OF NASA SCIENCE AND TECHNOLOGY

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BIOMEDICAL APPLICATIONS

OF

NASA SCIENCE AND TECHNOLOGY

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ABSTRACT

This final report covers the activities of the Research Triangle Institute's Biomedical Applications Team during the period from 15 June 1966 to 14 June 1967. The work reported here has been supported by NASA Contract NSR-34-004-035. This work was directed by Dr. J. N. Brown and has been under the general supervision of Dr. R. M. Burger, Director, Solid State Laboratory, Research Triangle Institute. (The remaining members of the team are RTI staff members Mr. Ernest Harrison, Engineer; Mr. J. W. Murrell, Physicist; Dr. H. G. Richter, Chemist; and, Mr. J. B. Tommerdahl, Engineer.) Consultants from medical and dental institutions to this program are Dr. E. A. Johnson, Professor of Cardiac Pharmacology, Duke University Medical Center, Durham, North Carolina; Dr. F. L. Thurstone, Professor and Director, Department of Biomedical Engineering, Bowman-Gray School of Medicine, Wake Forest College, Winston-Salem, North Carolina; Dr. M. K. Berkut, Professor of Biochemistry, UNC Medical School, Chapel Hill, North Carolina. Additionally, the following individuals have been of value to this program by acting as liaison between the applications team and the staffs at other medical institutions: for the Dental Research Center, School of Dentistry, University of North Carolina, Dr. A. D. Dixon, Assistant Dean; for Rockefeller University, Monte Fiore Hospital and the Albert Einstein Institute, New York, Dr. Lawrence Eisenberg, Professor of Electrical Engineering and for the Hospital for Special Surgery, New York, Dr. William Cooper, Director of Rehabilitation Medicine.

1.0 Introduction

This report summarizes the activities of the Research Triangle Institute's Biomedical Applications Team during the period from 15 June 1966 to 14 June 1967. During this contract period, the following objectives have been realized:

(1) A Biomedical Applications Team consisting now of four members has been organized at the Research Triangle Institute;

(2) Through interactions with biomedical researchers and clinicians at nine medical institutions approximately one hundred problems and needs existing in the biomedical field have been identified;

(3) In attempting to find solutions to these problems the applications team has prepared sixteen Biomedical Problem Abstracts, initiated eighteen computer information searches at the Science and Technology Research Center of the North Carolina Board of Science and Technology, and applied the experience of the team members and medical consultants at the participating medical institutions;

(4) The team has identified and evaluated solutions to seven biomedical problems and is presently in the process of evaluating or beginning to evaluate a number of possible solutions to other biomedical problems; and

(5) The team has continually analyzed its organization and function to determine the most effective method of serving as an interface between the physical and life sciences and has incorporated the results of these analyses into its own organization and function.

This report summarizes briefly completed transfers of technology and discusses those potential transfers which are most likely to come to fruition. The report also contains a discussion of the essential requirements for the most effective operation of Biomedical Applications Teams. Complete lists of biomedical problems and needs which have been identified by the team, biomedical problem abstracts and information searches which have been initiated are contained in the Appendices. The primary objectives of the Biomedical Applications Team are reviewed in the following sections.

2.0 Program Objectives

The Technology Utilization Division of the National Aeronautics and Space Administration is making very significant efforts to transfer the scientific and technological results of the nation's aerospace activities to industrial, educational, and medical institutions. There are many examples of success in this technology utilization program. At present, the transfer of science and technology to the biomedical field is becoming one of the major and most important activities within this technology utilization program. There are, however, some rather unique problems associated with the transfer of technology to problems and needs existing in the field of biomedicine. Many of these problems are related to the differences in both language and methodology used in the physical and life sciences.

In order to facilitate the transfer of scientific and technological information to clinicians and biomedical researchers, NASA is presently supporting three multidisciplinary "Biomedical Applications Teams". The

primary objectives of the Applications Teams are: (1) to identify medical-related problems and needs which appear to be "solvable" by the application of science and technology resulting from aerospace research and development programs; (2) to identify the specific technology or concepts which may lead to solutions of these problems; and, (3) to document these "transfers" of science and technology to achieve maximum utilization of the results of the program. An equally important objective of this team effort is to obtain an understanding of the difficulties encountered in applying the results obtained in the physical sciences to the problems and needs of entirely different disciplines such as medicine and biology. With this understanding, the teams are to adapt their operation toward achieving a more effective interface and information channel between the physical and life sciences.

In achieving these objectives, members of the Applications Team discuss specific problems which are being encountered in both biomedical research and the practice of medicine with researchers and clinicians at the participating medical institutions. These meetings are coordinated and, to a great extent, given direction and purpose by consultants taken from the staffs of the medical institutions. The team attempts to understand fully the nature of the problems and needs plus how they are affecting the progress of research or hindering patient treatment and care. Following these discussions, the team identifies very specific problems and attempts to express these problems in purely physical or engineering terminology. In some instances, a "Biomedical Problem Abstract" which gives a concise description of the problem is prepared and disseminated through the Technology Utilization Division of NASA

to the NASA Centers, as well as other organizations participating in the space program, in an attempt to uncover any information which may lead to a solution. At the same time, the team takes advantage of the services of NASA Regional Dissemination Centers such as those offered by the Science and Technology Research Center located adjacent to the Research Triangle Institute to obtain pertinent information. All information obtained resulting either from problem abstracts, information searches or through the experience of team members is then evaluated. This evaluation is aided by medical consultants as well as the researchers and clinicians who originated the problems. Finally, these teams both encourage and aid, when possible, the application or adaptation of technology which results from these activities.

In the following sections are contained discussions of the activities of the Biomedical Applications Team located at the Research Triangle Institute. This will include considerations of completed and potential transfers of aerospace technology and the evolution of the organization and functioning of the applications team to increase its effectiveness in general.

3.0 Program Summary

During the preceding year, the Research Triangle Institute has organized a Biomedical Applications Team consisting now of seven individuals having a variety of backgrounds in the physical and life sciences. The organization of this team will be described more completely in Section 4.0. To date, the team has been involved in activities at the following medical, dental, and research institutions:

Duke University Medical Center, Durham, North Carolina

Bowman-Gray School of Medicine, Winston-Salem, North Carolina

University of North Carolina Medical School, Chapel Hill, North Carolina

Dental Research Center, School of Dentistry, UNC, Chapel Hill, North Carolina

Veterans Administration Hospital, Durham, North Carolina

Rockefeller University, New York

Monte Fiore Hospital, New York

Albert Einstein Institute, New York

Hospital for Special Surgery, New York.

In this work, 102 different problems and needs have been identified. A complete list of these problems and needs is presented in Appendix A. In attempting to find solutions to these problems the team has prepared 16 biomedical problem abstracts and has initiated 18 computer searches of the aerospace literature at the Science and Technology Research Center located in the Research Triangle Park. Titles of the Biomedical Problem Abstracts and information searches and status of the searches are presented in Appendices B and C, respectively. Additionally, the team has made use of other available sources of information including its own background and experience in this effort. Finally, the team has continuously observed its progress in an attempt to adapt its operation toward becoming more effective as an interface between the physical and life sciences. The results of this part of our program are discussed in some detail in Section 4.0.

During the contract period, the Biomedical Applications Team has been successful in completing a number of technology transfers to the

medical field. Additionally, a number of potential technology transfers can be identified and are in the initial stages of evaluation. In the following paragraphs these completed and potential transfers are discussed very briefly. Included in these summaries is an indication of how the transfer was accomplished.

DU-6

Correction for Latency in Vidicons

Dr. E. A. Johnson, Professor of Pharmacology

Duke University Medical Center

Dr. Johnson has for some time been using a closed circuit TV system to monitor evoked contractions of cardiac muscle tissue. Since this tissue moves very rapidly with respect to the scan rate of conventional television systems, the image which is obtained is generally quite degraded. This results from both latency or storage time in the camera tube as well as from geometric distortion of the image caused by the significant movement of the tissue during a single frame.

In response to Biomedical Problem Abstract DU-6, a solution to this problem was suggested by Mr. Donald Buchele at Lewis Research Center. This solution consists of using a stroboscopic light source which is synchronized with the 60 per second non-interlaced framing rate of the closed circuit TV system. Initial experiments with stroboscopic lighting indicate that latency problems have been reduced to an acceptable level and can perhaps be completely eliminated. The stroboscopic lighting has now been installed as an integral part of Dr. Johnson's experimental equipment. Full advantage of this system has not been realized at present due to a malfunction in the associated video tape recorder. It

is fully expected however that, when the video recorder is functioning properly, this research program will be significantly enhanced as a result of Mr. Buchele's suggestion.

It is interesting to note that a number of people have felt that stroboscopic lighting is an obvious solution and one that should be thought of immediately. However, this is an after-the-fact observation and points to one of the real values of the Biomedical Applications Team concept. That is, the team can serve as a fairly strong interface between researchers and clinicians in the biomedical field and a very large number of individuals in the space and space-related programs who are experts or specialists in a particular field in the physical sciences. This solution may indeed have been obvious to Mr. Buchele at the Lewis Research Center, but it was by no means obvious to the people facing the problem with limited experience with this particular type of equipment.

WF-7

Correction for Spherical Aberration in Ultrasonic Holograms

Dr. F. L. Thurstone, Professor and Director
Department of Biomedical Engineering, Bowman-Gray School of Medicine

Dr. Thurstone is presently investigating a unique technique for displaying the structure of internal organs of the human body. This technique involves the generation of an optical hologram from the information contained in ultrasonic energy reflected from these organs. There are primarily three reasons for this present investigation. First, ultrasonic energy does not appear to be dangerous to the body as are X-rays. Second, ultrasonic energy is reflected from interfaces between different types of soft tissue and therefore allows visualization of structures

which cannot be "seen" in radiographic images. Third, the image obtained with an ultrasonic hologram is three-dimensional.

Since the ultrasonic hologram is constructed from information obtained using ultrasonic energy having a wavelength of approximately 0.3 millimeters and the optical images are reconstructed using light having a wavelength approximately 3 orders of magnitude smaller, the reconstructed image contains significant spherical aberration. This aberration appears as a general degradation of the image.

A possibility for removing this spherical aberration was identified in the digital image processing facility at NASA's Jet Propulsion Laboratory. Dr. Robert Nathan and Mr. Robert Selzer at JPL have been very cooperative in writing a computer program for the spherical aberration correction and this correction has been performed in an ultrasonic hologram supplied by Dr. Thurstone. Because of the nature of this particular hologram and the small size of the reconstructed image (approximately 0.25 inches) a quantitative evaluation of the corrected hologram has not been made. However, a general improvement of the reconstructed image obtained using the corrected hologram was observed. Perhaps equally important is the fact that it has been demonstrated that holograms can be processed without degradation being introduced by the scanning and digitizing processes.

This approach for spherical aberration corrections was obtained through a response from JPL to a Biomedical Problem Abstract describing an entirely different problem (Problem Abstract DU-1, Calculation of Left Ventricular Volume). In discussing DU-1 and digital image processing

with Dr. Thurstone, he observed that image processing represented a possible solution to his own problem of aberration in ultrasonic holograms. Following this, Drs. Thurstone and Brown visited JPL to discuss ultrasonic holography and image processing in general with Dr. Nathan and Mr. Selzer. Dr. Nathan was, as a result of his considerable experience in crystallography and image processing, able to make a number of suggestions for improving the investigation of ultrasonic holograms. These suggestions included methods of correcting for source and sensor apertures and gamma and spatial filtering techniques to remove systematic noise in the holograms. Dr. Thurstone is presently beginning to incorporate a number of changes in his system which will facilitate digital image processing and make this processing more effective.

UNC-12

Low Temperature Lubricant for Microtomes

Dr. William Waddell, Assistant Director

UNC Center for Research and Pharmacology and Toxicology

Obtaining good tissue samples requires very rapid freezing to minimize damage to the tissue by water crystallization. This requirement means that the tissue must be frozen using very low temperatures and further that these low temperatures be maintained while they are sectioned using a microtome. At the temperature of liquid nitrogen, the ordinary lubricants used on microtomes are totally unsatisfactory. The solution to this problem was found in NASA document SP-5059, Solid Lubricants, which is one of a number of surveys that are continually being collected by the Biomedical Applications Team. A molybdenum disulfide preparation and a teflon dispersion were suggested as possible

lubricants. Dr. Waddell has found that the latter lubricant is very appropriate for this application. The teflon dispersion is now being used routinely as a low temperature lubricant for microtomes.

WF-10

Aberrations in Holography

Dr. F. L. Thurstone, Professor and Director

Department of Biomedical Engineering, Bowman-Gray School of Medicine

In his investigations of ultrasonic holography, Dr. Thurstone has a need to understand and have quantitative expressions for the various aberrations which occur in holography. Simple mathematical treatments of holography do not give the higher-ordered aberrations and distortions which occur because of the assumptions made in the analyses. An information search was initiated at the Science and Technology Research Center to obtain information on holography theory, ultrasonic imaging techniques, and related technologies. One report resulting from this search has been of very significant value to Dr. Thurstone in his work.* This particular article contains an analysis of high-order aberrations of different types which occur in holography. The derivations of these terms are in general very complex and time consuming, and as a result this particular information search has been of considerable value.

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* Reinhard W. Meier, "Magnification and Third-Order Aberrations in Holography," J. Optical Society of America, Vol. 55, No. 8, August 1965, pp. 987-992.

UNC-9

Analysis of Electrophoretic Scan Data

Dr. J. J. Van Wyk, Professor of Pediatrics and Endocrinology
University of North Carolina Medical School

Dr. Van Wyk is presently investigating the effects of growth hormones on midget infants by a radio-immunoassay technique. Each experiment results in approximately 150 electrophoresed samples which are taped end-to-end and passed through a radioactivity strip counter. The resulting radioactivity scans must be examined by Dr. Van Wyk and the activity peaks identified and separated. The areas under these peaks which are representative of quantities of different materials in the samples are then determined with a planimeter. This manual determination of areas, which is performed by student-wives, is both time consuming and fallable and is the weak link in the entire process. At present, several months of data are waiting for analysis.

Several alternative techniques were suggested. In view of the fact that Dr. Van Wyk wants to continue to perform the initial inspection of the radioactivity scans, only one of these approaches appears applicable. This involves cutting the original electrophoresed samples at points indicated by the visual inspection of the radioactivity scans. The areas, or quantities of materials, are obtained by a determination of total activities of these sample sections using a counter with an automatic sample changer. The resulting digital data obtained in this manner are convenient for recording and are obtained more rapidly.

This particular transfer was a result of the experience and familiarity of one of the members of the applications team with radioisotope techniques and instrumentation.

UNC-2

Bone Growth and Resorption Mechanisms

Drs. D. L. Allen and W. T. McFall

Dental Research Center, University of North Carolina

Drs. Allen and McFall are primarily interested in methods of stimulating bone growth electrically as a means for rebuilding the tooth-supporting bone tissue which has been resorbed. The applications team has designed a simple mechanism which allows direct current stimulation of bone tissue on rat skulls without significantly restricting the normal activity of the rats. The Research Triangle Institute has supplied 12 of these mechanisms to the Dental Research Center to allow the initial experimental work to begin. Additionally, the Solid State Laboratory at RTI has begun in vitro studies of the electrical properties of bone tissue. These experiments are designed to gain some understanding of growth and resorption processes in bone and how these processes are affected or controlled by electrical charge distributions in tissue.

It has been suggested by Bassett* that both growth and resorption of bone tissue are controlled by electrical phenomena. Also, it has been demonstrated that bone tissue is piezoelectric and that this piezoelectric characteristic of bone tissue may serve as the primary feedback mechanism involved in the process of strengthening bone tissue which is regularly subjected to relatively large amounts of mechanical stress. It is possible that the loss of calcium in skeletal bone in astronauts results from the absence of mechanical stress in the skeleton in this

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* C. A. L. Bassett, "Electrical Effects in Bone," Scientific American, Vol. 213, Oct. 1965, pp. 18-25.

weightless environment. It is hoped that some method for applying the results of space flights can be applied to increasing the understanding of these phenomena in general.

UNC-13

Reinforced Braces and Casts

Miss Florence Bearden, Head of Occupational Therapy

University of North Carolina School of Medicine

Arthritic patients frequently must wear braces or splints to maintain use of their hands and joints. The patients frequently expose their splints, which are made from a thermoplastic material, to intense sunlight or hot water which destroys the splint. It was suggested that fiberglass reinforcement might alleviate the problem. Preliminary experiments have been made and indicate that this approach can solve the problem. The Occupational Therapy group plans to conduct feasibility tests on full splints.

DU-1

Calculation of Left Ventricular Volume from Cineradiographs

Dr. Henry D. McIntosh, Professor of Medicine

Duke University Medical Center

Blood volume and pressure within the heart chambers, particularly the left ventricle, as a function of time are important parameters in diagnosing a variety of heart diseases. Dr. McIntosh as well as other individuals at Duke University and the University of North Carolina are extremely interested in techniques of automating the calculation of volume inside the left ventricle from biplane cineradiographs of the heart. A response to Biomedical Problem Abstract DU-1 from Mr. John Warden at the Jet Propulsion Laboratory indicated that digital image

processing techniques could possibly be developed for completely automating this calculation of ventricular volume. Cineradiographs of the heart have been sent to Dr. Robert Nathan and Mr. Robert Selzer of JPL to obtain their opinion of the feasibility of this approach and to get some ideas of how it can be accomplished. Dr. Nathan feels that at least a part of the volume determination can be automated, and he and his associates at JPL have indicated that when time permits they will do some initial feasibility studies of this application of digital image processing.

UNC-1

Oxygen Measurements in Gas Mixtures

Dr. K. Sugioka, Head, Division of Anesthesiology
Department of Surgery, University of North Carolina Medical School

The need for a highly reliable method of measuring oxygen partial pressure and flow rate in anesthetic gas mixtures is described in Problem Abstract UNC-1. A number of responses to this abstract have been obtained from the Technology Utilization Officer at JPL as well as from North American Aviation, Inc. However, due to the complexity and nature of the instrumentation involved evaluations of these responses are expensive, complex, time-consuming, and not completed.

The use of a thin film oxygen detector being developed at the Research Triangle Institute under a NASA Contract has also been studied. Initial experiments indicate that the thin film sensor can detect oxygen partial pressure in anesthetic gas mixtures. However, the high sensor temperature which is required is possibly causing detrimental chemical reactions in the anesthetic mixture. Further investigations are necessary to complete this evaluation.

DU-7

Microforce Transducer

Dr. E. A. Johnson, Professor of Pharmacology

Duke University Medical Center

In studying the contractile characteristics of cardiac muscle tissue, Dr. Johnson needs to be able to measure forces generated within single muscle fibers. These forces range from .01 to 1 milligram, and the transducer must have a relatively high frequency response. A concept for measuring very small forces based on the operation of a piezojunction pressure transducer being developed at RTI under a NASA contract has been identified as a possible solution to this problem. Evaluations of the force transducer have been held up because of mechanical stability problems which exist in the device. A modification of the transducer mechanical configuration will be necessary.

UNCD-7

Narrow Depth of Field Dental X-rays

Dr. C. E. Crandell, Professor of Oral Diagnosis

University of North Carolina Dental Research Center

Currently available dental X-ray machines using laminographic techniques can be used to obtain records on ordinary flat film of the entire tooth structure. This represents a significant advance over conventional techniques, but it has one limitation which is frequently a disadvantage. The depth of focus of such units is approximately one-half inch. Frequently, the dental clinician is interested in a much narrower range of focus in order to study specific layers or portions of the teeth. We have discussed this problem with the researcher and have performed a selective literature search of related documents available locally and

in our files. A technique to obtain a very small depth of focus was encountered in the Proceedings of the Second Technology Status and Trends Symposium presented in 1966 at Marshall Space Flight Center.* An adaptation of this technique, axial transverse laminography, was suggested as a possible approach to this problem. A copy of the original article plus the adaptation was given to the researcher. He is presently evaluating this technique.

UNCD-6

Temperature Measurement of Teeth

Dr. C. E. Crandell, Professor of Oral Diagnosis

University of North Carolina Dental Research Center

The temperature of the pulp of the tooth is considered to be an indicator of the condition of the tooth; however, there are no currently available devices to reliably measure the temperature of an individual tooth "in vivo". Infrared scanning techniques have been applied without success. Investigations were made preliminary to writing a problem abstract for a device to perform this measurement; however, a persual of articles by researchers who have tried infrared scanning has created some doubt as to whether the basic problem is an equipment problem or an improper approach to the problem. We feel that the fundamental thermodynamic restraints on the overall problem have not been fully appreciated by some of the investigators. An examination is currently underway to analyze the problem from a heat flow standpoint to determine optimum techniques and actual device requirements.

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* George C. Marshall Space Flight Center, Proceedings of the Second Technology Status and Trends Symposium, Huntsville, Alabama, October 26-27, 1966.

UNCD-10

Dental Thermography

Dr. C. E. Crandell, Professor of Oral Diagnosis
University of North Carolina Dental Research Center

Thermography using infrared scanners, discrete IR sensors, and liquid crystals has been employed as an aid to diagnosis in the detection of near-surface cysts, malignant tissue, and an ever-expanding list of other applications. A researcher at UNC Dental School has attempted to apply IR scanners to the detection of malignant tissue in the mouth, but preliminary attempts have produced no reliable diagnostic information. An evaluation of basic approaches to the measurement problem is underway. The application of liquid crystals to this problem is under consideration. Mr. James Beal, a NASA authority at Marshall Space Flight Center on liquid crystals has been consulted, and he has provided information which is now being applied to the problem. The usual method of employing liquid crystals requires painting a black base and a film of liquid crystals on the surface to be examined. We are working on a technique which does not require direct contact. Such a technique would provide a many-fold increase in flexibility. Preliminary calculations indicate that this approach is feasible, and work on the development of this technique is continuing.

WF-13

Intracavitary Radiation Probe

Mr. Clay Watts, Department of Radiology
Bowman-Gray School of Medicine

According to Mr. Watts, the techniques presently used for measuring dose in radiation therapy do not in fact give one a measure of tissue

dose. Rather, what is determined is exposure to radiation. There is a need for a technique of measuring radiation levels inside body cavities and tissue. NASA Tech Brief 66-10252 describing a biomedical radiation probe lead the Biomedical Applications Team to contact Mr. John T. Wheeler at the Manned Space Craft Center in Houston. Mr. Wheeler indicated that Solid State Radiation, Inc., in Palo Alto, California, has done considerable development of probes and sensors for NASA and the Atomic Energy Commission. Dr. Henry Katzenstein, President of Solid State Radiation, Inc., was contacted,and a meeting of Dr. Katzenstein and members of the medical staff at the Bowman-Gray School of Medicine was held at the Research Triangle Institution in May, 1967. During the meeting, the discussion centered around the feasibility of beta detection and alpha particle detection in the body using solid state detectors and the physiological and medical significance of these determinations. Dr. Katzenstein agreed to supply the Bowman-Gray School of Medicine with experimental radiation detectors to aid the evaluation of solid state intracavitary radiation detection.

WF-3

Prosthetic Urethral Valve

Dr. William G. Montgomery, Department of Urology

Bowman-Gray School of Medicine

The need for a fluid valve which can be implanted in the male urinary tract to control the flow of urine is described in Biomedical Problem Abstract WF-3. The most significant requirements on this valve are that it be controllable by the patient and that no part of the valve pass through the skin or outside the body through the external urethra.

At present, Dr. Montgomery and his associates are experimenting with a small ball valve which is operated by an electromagnet in the body of the valve. The power to actuate the valve when implanted would be transmitted into the body by electromagnetic radiation. The applications team has been of assistance in the design of the magnetic circuit which activates the valve. Dr. Thurstone, team consultant, has been very active in all phases of the valve design and has had experimental models fabricated in his model shop at the Bowman-Gray School of Medicine.

4.0 Biomedical Applications Team Organization and Function

As stated in Section 2.0, the primary objectives of this program are to identify technology-related biomedical problems and NASA-generated technology having some bearing upon solutions to these biomedical problems. This is followed by evaluation of possible solutions and, when possible, aiding the application of solutions in hospitals and research laboratories. Additionally, a significant part of the program is directed toward obtaining a better understanding of the methods employed in accomplishing technology transfers in the biomedical field. It is felt that in the past year we have gained sufficient insight into this process to significantly increase the effectiveness of the team's efforts. These improvements in our program involve both the organization of the team and the methods employed in obtaining information which can lead to solutions to problems in the biomedical field. These points are discussed in the following paragraphs, and it is indicated how the team at RTI has modified its activities to realize a more successful operation.

First, and perhaps most importantly, is the manner in which the team members interact with clinicians and researchers at the medical

institutions. In these interactions the most important factor is obtaining a clear understanding of the medical problems and how possible solutions would be used. This understanding of the problem can be achieved most efficiently when the applications team member has some experience in the general scientific and technological field which is involved. To implement this matching of experience with problem areas, the responsibilities of the team members are delineated according to problem area. Initially these responsibilities were dictated geographically. The present assignment of problem areas for the members of the applications team is as follows:

(1) Dr. J. N. Brown, Jr., Director, Biomedical Applications Team, electronic systems and image processing.

(2) Mr. Ernest Harrison, Jr., Engineer, materials science and optical and mechanical systems.

(3) Mr. J. W. Murrell, Physicist, transducers (solid state, capacitive, etc.) and monitoring systems.

(4) Dr. H. G. Richter, Chemist, radioisotope tracing and monitoring and chemical analysis techniques.

Additionally, it has been found that our understanding of the biomedical problems and needs is greatly enhanced as the number of meetings with individuals within the medical institutions is increased. In fact, more than an increased understanding of the problem is involved here. What frequently happens is that through repeated meetings we will shift our focus from a somewhat superficial problem to a more basic but related problem. Finally, it has been found that, although it is highly desirable that our consultants be present at all these discussions, it is necessary

that a team member be present. That is, it is more preferable to work with our consultants than to work through a consultant.

The problem abstract concept is theoretically one of the most effective means for identifying advanced technology which can be applied to problems identified in the biomedical field, as well as other fields. It represents a means for bringing together individuals which are separated both geographically and by profession. Further, it represents a method of collecting ideas from a large number of people in many different disciplines. To be effective, however, the Problem Abstract must be well conceived and written. Based upon the experience of NASA's Technology Utilization Division, as well as our own, the following guidelines are being used in the preparation of Biomedical Problem Abstracts. A problem abstract must:

(1) State the problem concisely with emphasis on functional requirements, and

(2) Show significance of possible solutions to medical research, clinical practice or patient treatment and care.

The problem abstract should not:

(1) Limit possible approaches to solutions,

(2) Request solutions or information which can be obtained by searching the literature or other more direct means, or

(3) Present problems which appear to be "impossible" or are generally known to require relatively long periods of research and development.

In addition to the Biomedical Problem Abstract approach to obtaining information related to medical problems and needs, the applications teams

have access to NASA Regional Dissemination Centers such as the Science and Technology Research Center in the Research Triangle Park. Through these centers, one can search the open literature as well as aerospace government reports and documents. The effectiveness of this information searching depends upon one's understanding of what he is searching for and his experience in making information searches. We have found that the RDC can be extremely valuable to this program in ways other than simply allowing us to search computer tapes containing aerospace articles and reports. The RDC personnel generally become very familiar with NASA programs and industrial research and development programs supported by NASA. They have frequently directed us to contact individuals at NASA centers who have been able to furnish information related to specific problems and needs. Further, they have frequently suggested NASA-generated technology surveys which were pertinent to specific problem areas. In general, we have found that contacts with individuals made through the Science and Technology Research Center have been at least as valuable as the results obtained from the computer information searches. Finally, to facilitate this information searching part of the program, we are attempting to build up a complete file of survey and state-of-the-art types of reports as well as NASA program reports. Having this kind of information on hand is of great value in rapidly identifying activities within NASA which are pertinent to specific biomedical problem areas.

In summary, the contents of the preceeding paragraphs can be stated quite briefly in the following manner. Biomedical problems and needs and their significance must be clearly understood. This understanding is

achieved by frequent discussions between biomedical personnel and team members having the appropriate background and experience. Biomedical Problem Abstracts must be understandable and complete and should discuss only significant and, at the same time, "solvable" problems. Success in searching for information through regional dissemination centers is achieved by experience and working directly with the center staff. Finally, it is important that the team maintain an up-to-date and complete file of technology surveys and NASA program reports.

5.0 Conclusions

This report has presented a review of the primary objectives of Biomedical Applications Teams. It has, further, presented a summary of the activities of the RTI applications team during its first year of operation. Also, the effectiveness of the Biomedical Applications Team concept has been analyzed and recommendations for the most effective functioning of such teams were presented. In summary, the RTI applications team has been effective in identifying significant technology-related biomedical problems and has directed its efforts toward obtaining solutions for a number of these problems. As a result, solutions to seven problems have been identified and evaluated. A number of other solutions has also been identified and evaluations are, at present, being initiated. The applications team has continually adapted both its organization and function to achieve a greater transfer of technology to the biomedical field. These adaptations include the following:

(1) Team members have increased the frequency with which they discuss problems and needs with biomedical researchers and

clinicians to obtain better understandings of the problems and their significance;

(2) Team members are becoming specialized in different areas of science and technology which are known to be important in the biomedical field so that they can discuss specific problems and needs more intelligently from the introduction of the problem;

(3) The team is building up a complete and up-to-date file of survey and state-of-the-art type program reports in an effort to respond more rapidly to specific problems as well as to be able to identify quickly programs which should result in knowledge and technology pertinent to specific problem areas.

In conclusion, the RTI Biomedical Applications Team has been successful in applying aerospace technology to problems existing within the biomedical field,and the team has developed or improved methods for maximizing this transfer of technology. It is recommended that this program be continued with the primary objective being to apply the experience which has been gained by the RTI applications team toward achieving a maximum number of transfers from the physical sciences in general and the space program in particular to the field of biomedicine. Further, this effort should involve concentrating upon those problems and needs of biomedicine which are known to be closely related to technology and upon those areas of technology which are most applicable to the biomedical field.

APPENDICES

APPENDIX A

Biomedical Problems

Duke University Medical Center

DU-1 .... Techniques for calculating left ventricular volume from biplane cineradiographs.

DU-2 .... Method for monitoring NAD in living brain tissue.

DU-3 .... New techniques for constructing safe and efficient hemodialyzers.

DU-4 .... Measurement of extremely small temperature changes.

DU-5 .... Electromyographic electrode assembly for the soft palate.

DU-6 .... Correction for latency in vidicons.

DU-7 .... Microforce transducer for single cardiac muscle fibers.

DU-8 .... Methods of studying quantitatively diseased membranes in body joints.

DU-9 .... A 4-channel telemetry system to be used in experiments with dogs.

DU-10 ... Techniques for monitoring heart rate, rapid changes in blood pressure, and detecting arrhythmias directly and automatically from physiological data.

DU-11 ... Pressure transducers for intracavitary or subcutaneous implantation in the body.

DU-12 ... Techniques for enhancing cineradiographs of kidneys so that the arterial network within the kidney can be mapped.

DU-13 ... Sources of K42 having very high specific activity.

DU-14 ... Spray-on electrode.

DU-15 ... Techniques for analyzing carotid artery pressure pulse to obtain blood flow data.

DU-16 ... Visual discrimination in photos and X-ray pictures.

DU-17 ... Storage and retrieval of biomedical text.

DU-18 ... Special purpose real time data processing.

DU-19 ... Low costs microminiaturized and reliable time multiplexing and A/D electronic equipment.

DU-20 ... Multielectrode needles.

DU-21 ... Method of measuring radial component of ionic current flow through nerve membrane.

DU-22 ... Method of alternately exposing tissue to two separate monochromatic light beams having different wavelengths at a rate of 5,000 cps.

DU-23 ... Methods of improving resolution and general quality of electron micrographs to obtain more information on the structure of cell membranes.

DU-24 ... Instrumentation for obtaining EKG of developing chick embryo heart.

DU-25 ... A signal conditioning and multiplexing system for multiple electrode EKG patient monitoring.

Bowman-Gray School of Medicine, Wake Forest College

WF-1 .... A technique for generating an ultrasonic noise spectrum with a variable and sharp low frequency cut-off characteristic.

WF-2 .... A mechanism for holding ultrasonic transducers to the skull.

WF-3 .... Prosthetic valve for urinary tract.

WF-4 .... Small aperture ultrasonic transducers having large capture angle.

WF-5 .... Method of photographing ultrasonic energy patterns.

WF-6 .... Seven-channel, portable, battery-operated tape recorder. The recorder must be light-weight and should operate for at least eight hours.

WF-7 .... Method of correcting for spherical aberration in ultrasonic holograms.

WF-8 .... Techniques for analyzing and obtaining all significant information contained in ultrasonic echo pulses.

WF-9 .... Materials for prosthetics.

WF-10 ... Theoretical treatments of holography which discuss aberrations and distortions.

WF-11 ... Mechanical joints, extensions, etc., that can be used in powered prosthetics. Also needed are control systems, either electrical or fluid, for operating these mechanisms.

WF-12 ... Variable diameter probe for electromagnetic, blood flow meter.

WF-13 ... Radiation detector for in vivo measurement of absorbed dose.

WF-14 ... Spin resonance studies of physiological tissue which has been exposed to radiation.

WF-15 ... Information on damage to physiological tissue exposed to low levels of radiation.

WF-16 ... Low noise coaxial cable for use in recording electroencephalograms.

WF-17 ... Helmet containing electroencephalograph electrodes.

WF-18 ... Techniques for averaging evoked nerve responses that are simpler and less expensive than commerically available instruments.

WF-19 ... A method for stimulating nerve tissue from outside the body.

WF-20 ... A technique for continuously monitoring the inside and outside diameter of capillaries and small arteries and veins.

WF-21 ... A method of measuring velocities of individual red cells.

WF-22 ... Improved methods for presenting and enhancing autoradiographic scan data.

WF-23 ... An effective respirator for infants.

WF-24 ... Respirator control system that adjusts both volume and rate as well as other parameters according to body needs determined by monitoring continuously the partial pressures of gasses in the blood stream.

University of North Carolina Medical School

UNC-1 .... Oxygen measurement in gas mixtures.

UNC-2 .... Data on physiological calcium loss in weightless environments which may be relevant to understanding mechanisms of bone growth and resorption in the human body.

UNC-3 .... The effects of drugs upon mental and physical activity in space.

UNC-4 .... Information on biological rhythms obtained in aerospace research programs.

UNC-5 .... Techniques for facilitating the insertion of needles into small arteries and veins.

UNC-6 .... Implantable plastic materials.

UNC-7 .... Determination of radiation dose as function of position of radioactive needles or wires in body.

UNC-8 .... Method of monitoring complete activity of mice.

UNC-9 .... Analysis of electrophoretic radioactivity scan data.

UNC-10 ... A portable lightweight, and inexpensive EKG tape recorder.

UNC-11 ... A semi-portable instrument for measuring blood pressure which is not subject to operator error.

UNC-12 ... Low temperature lubricant for microtomes.

UNC-13 ... Methods of reinforcing thermo-plastic braces and casts.

UNC-14 ... Techniques for soldering aluminum.

UNC-15 ... Method of quickly and accurately measuring the angles which each finger segment makes with adjacent segments.

UNC-16 ... Technique for identifying all the amino acids in urine quickly.

UNC-17 ... Better materials for microtome knives than the presently available steel or glass.

UNC-18 ... Method for cooling a few mm^3 tissue specimen from body temperature to -80°C in a few milliseconds.

UNC-19 ... Methods of sterilizing dental instruments in the clinic or office, quickly and positively, in one or two minutes, without heat or ethylene oxide.

UNC-20 ... Good micro-methods for determination of fatty acids.

UNC-21 ... Simple techniques for telemetering blood pressures.

UNC-22 ... Methods to identify quickly what a drug-intoxicated person has ingested as soon as he is admitted to the emergency ward.

UNC-23 ... Implantable materials besides teflon and silastic.

UNC-24 ... Oxygen-sensitive electrodes in the micron-size range.

UNC-25 ... Methods for detecting (screening) skeletal or straited muscle relaxants.

UNC-26 ... Better assay methods, other than bioassay, for succinyl dicholine at the microgram per milliliter level in serum.

UNC-27 ... Any method for assay of succinyl monocholine in serum.

UNC-28 ... Technique for measuring free fatty acids in serum.

UNC-29 ... Techniques for maintaining blood sugar at a constant level over a period of several hours.

UNC-30 ... What parameters other than blood sugar and fatty acid levels can be used to follow utilization of insulin.

UNC-31 ... Techniques for measuring metabolic products of anesthetics in breath and body fluids.

UNC-32 ... Method for measuring-externally-the extent of atherosclerosis.

UNC-33 ... Techniques for recording or telemetering heart rate and respiration of swimming and diving animals.

Dental Research Center, University of North Carolina

UNCD-1 ... A method of producing silver-copper and silver-tin alloys in powder form with spherical shape and with particle sizes in the range of 2 to 4 and 6 to 10 microns.

UNCD-2 ... Method of measuring change in width of mandible when closed and opened.

UNCD-3 ... A method for sterilizing dental instruments. The method must be rapid and should not require temperatures above approximately 200°C except on the surface.

UNCD-4 ... Technique for determining mechanical stability of teeth.

UNCD-5 ... An improved and reliable electric tooth pulp tester.

UNCD-6 ... A sensor to measure the temperature of individual teeth in such a fashion as to determine the viability of the tooth.

UNCD-7 ... A method of obtaining X-ray films of the entire mouth on a single film with a depth of focus of 1 mm or less.

UNCD-8 ... A reliable automatic processor for dental X-ray film.

UNCD-9 ... System for automatic scanning and statistical analysis of electron and photomicrographs.

UNCD-10 .. Techniques of applying thermography to the mouth.

Durham Veterans Administration Hospital

VA-1 .... Improved techniques for measuring blood flow continuously.

VA-2 .... Implantable catheters with outside diameter of approximately 10 thousandths of an inch suitable for measuring blood pressure without loss of high frequency signal.

VA-3 .... Transducers which can measure absolute blood pressure and are external to the body.

Hospital for Special Surgery

HSS-1 ... A method of measuring and telemetering the force applied to broken bone joints by implanted braces.

HSS-2 ... A method for measuring and telemetering pressures on the surface of prosthetic hip joints.

Rockefeller University

RU-1 .... A survey of computer techniques for analyzing physiological data.

RU-2 .... A survey of recently developed transducers for monitoring physiological parameters.

Albert Einstein Institute

AEI-1 ... Multiple electrode implant for communicating with brain.

AEI-2 ... A cathode ray tube camera for ultrasonic scanning systems.

Monte Fiore Hospital

MFH-1 ... Special materials to be used in new hospital construction.

APPENDIX B

Biomedical Problem Abstracts

Duke University Medical School

DU-1 .... "Heart Blood Volume Measurements"

DU-2 .... "Optical Scanning Concept"

DU-3 .... "Disposable Dialyzer"

DU-4 .... "Measurement of Small Temperature Changes"

DU-5 .... "EMG Electrode Assembly for the Soft Palate"

DU-6 .... "Correction for Latency in Vidicons"

DU-7 .... "Micro-force Transducer"

University of North Carolina

UNC-1 ... "Oxygen Measurements in Gas Mixtures"

UNC-2 ... "Information Related to Bone Growth and Resorption"

UNC-5 ... "Inserting Needles into Veins"

University of North Carolina Dental School

UNCD-1 .. "Preparation of Metallic Powders from Silver Alloys"

Bowman-Gray School of Medicine, Wake Forest College

WF-1 .... "Audio Noise Generator"

WF-2 .... "Ultrasonic Transducer Positioner"

WF-3 .... "Prosthetic Urethral Valve"

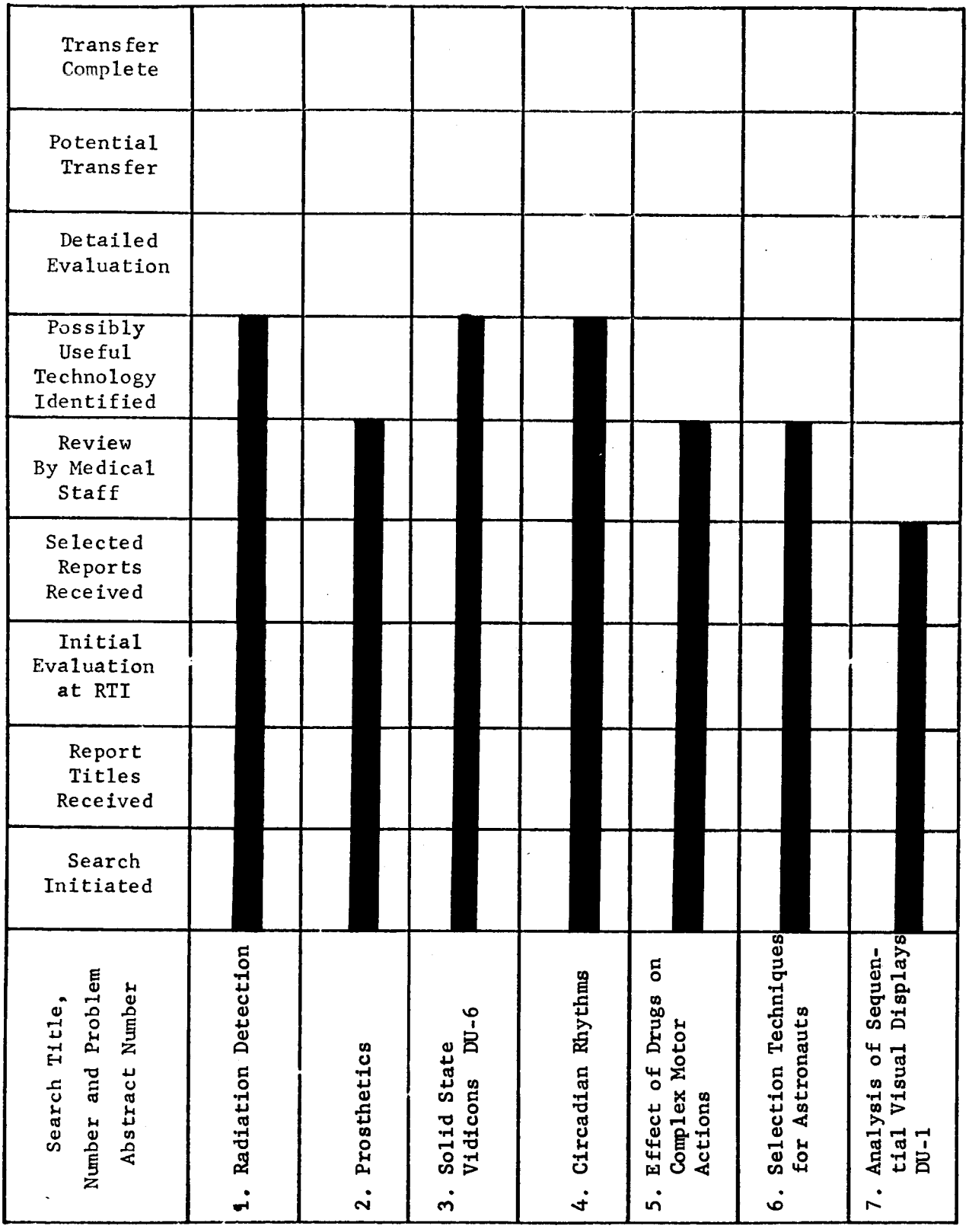
WF-4 .... "Non-directional Small-aperture Transducer for Ultrasonic Holograms"

WF-5 .... "Ultrasonic Image Recording"

APPENDIX C

Status of Information Searches

Status of Information Searches



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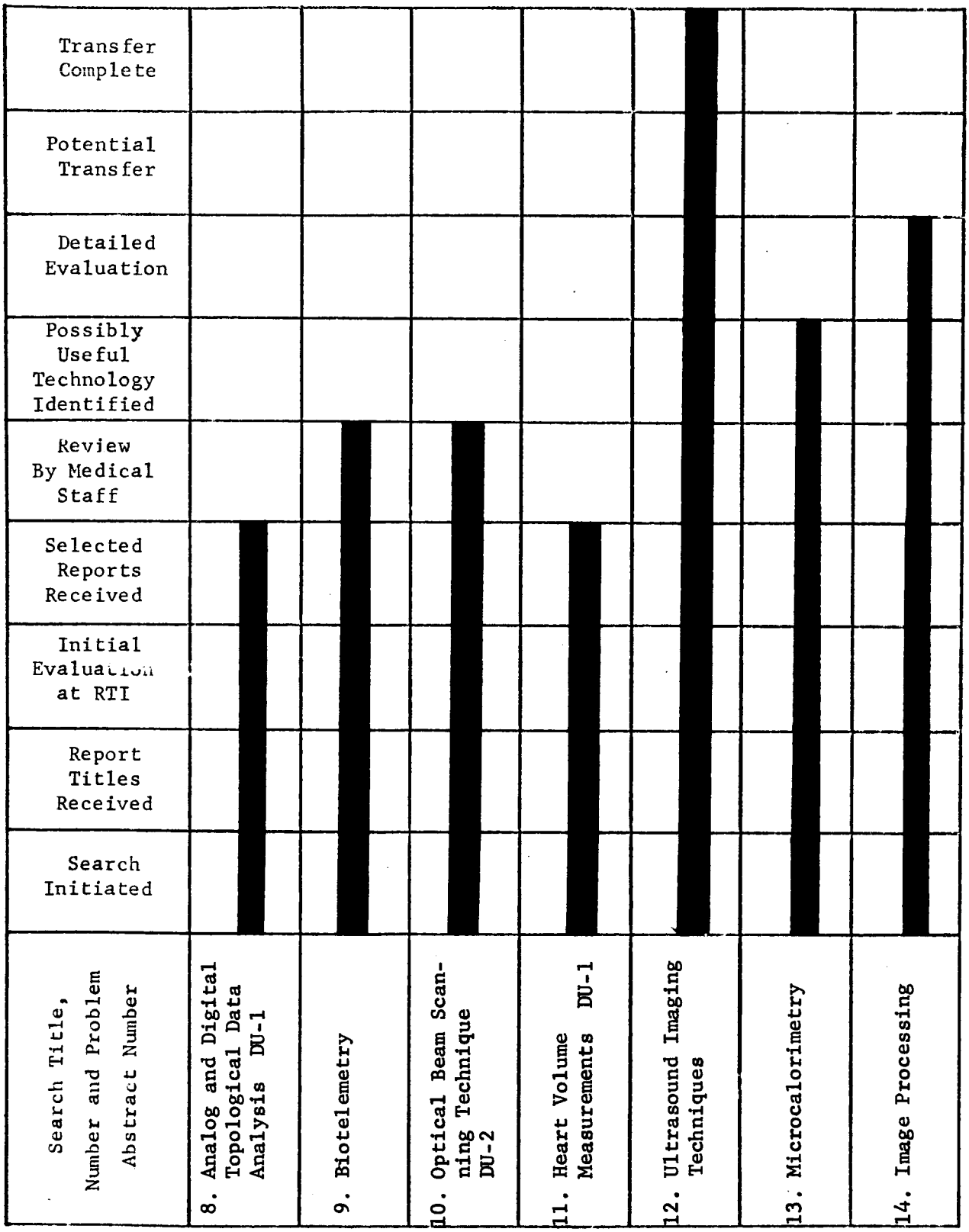

Status of Information Searches